AD-A039 794 INDIANA UNIV BLOOMINGTON DEPT OF CHEMISTRY F/G 20/6
SPECTRAL AND NOISE CHARACTERISTICS OF A 300-W EIMAC ARC LAMP.(U)
MAY 77 R L COCHRAN, G M HIEFTJE N00014-76-C-0838
UNCLASSIFIED TR-4 NL

1 OF 1
AD
A039794

END
DATE
FILMED
6-77

(12)
NW

OFFICE OF NAVAL RESEARCH

Contract N00014-76-C-0838

(14) TR-4

Task No. NR 051-622

(9) TECHNICAL REP[redacted]T NO. 4

(6) Spectral and Noise Characteristics of a 300-W Eimac Arc Lamp

by

(10) Ronald L. Cochran [redacted] Gary M. Hieftje

Prepared for publication in

ANALYTICAL CHEMISTRY

(15) N00014-76-C-0838

Indiana University
Department of Chemistry
Bloomington, IN

(11) 15 May [redacted]77 (12) 22p.

176685

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER 4	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) SPECTRAL AND NOISE CHARACTERISTICS OF A 300-W EIMAC ARC LAMP		5. TYPE OF REPORT & PERIOD COVERED Interim technical report
		6. PERFORMING ORG. REPORT NUMBER 4
7. AUTHOR(s) Ronald L. Cochran and Gary M. Hieftje		8. CONTRACT OR GRANT NUMBER(s) N00014-76-C-0838
9. PERFORMING ORGANIZATION NAME AND ADDRESS Department of Chemistry Indiana University Bloomington, IN 47401		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS NR 051-622
11. CONTROLLING OFFICE NAME AND ADDRESS Office of Naval Research Washington, D.C.		12. REPORT DATE May 11, 1977
		13. NUMBER OF PAGES 22
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report) UNCLASSIFIED
		15a. DECLASSIFICATION DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

Prepared for publication in ANALYTICAL CHEMISTRY

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Eimac lamp	noise frequency
Xenon lamp	image quality
S/N	

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

A 300-W, integral-parabolic-reflector Eimac lamp is evaluated for use as a spectrometric continuum source. The spectral radiant power (W/nm) available in the lamp's output beam is measured and compared to that available from a more common 150-W high pressure xenon short-arc lamp. The Eimac lamp is shown to provide up to 37 times more radiant power than the 150-W lamp.

The Eimac lamp's signal-to-noise characteristics, noise frequency distribution, integral reflector optical quality, and arc image quality are also

(continued on back)

20. ABSTRACT (continued)

discussed. It is shown that the signal-to-noise ratio of radiation emerging from different parts of the Eimac lamp's output window can vary by a factor of about 5, indicating that care should be taken when using spatially selecting optics with this source.

High-pressure xenon short-arc lamps have long been considered to be reliable, high intensity sources of radiation for the ultraviolet, visible, and near-infrared spectral regions. The Eimac illuminator series, which Varian began marketing in 1972, is a variant of the conventional short arc lamp, having an integral parabolic (or elliptical) reflector, which provides greatly improved light gathering efficiency over more simple arc lamps. The integral reflector also significantly simplifies lamp alignment.

The 150-W Eimac illuminators have been employed and their performance evaluated in several analytical applications. Various workers in the laboratories of J.D. Winefordner have evaluated for use as atomic fluorescence excitation sources both integral-elliptical-reflector (1-3) and integral-parabolic-reflector (4) Eimac lamps. It was determined that the extremely high spectral radiance provided by the integral-elliptical-reflector lamp made this source particularly well suited for AFS.

Zander and Keliher (5) employed a 150-W integral-parabolic-reflector lamp as a primary source in continuum-source atomic absorption spectrometry and found its performance superior to that of a conventional 200-W Hg-Xe arc lamp for that application. Perchalski, et al., (6) have thoroughly evaluated an identical Eimac arc lamp as a source for molecular fluorescence spectrometry. In their work, the Eimac lamp was shown to provide a two-to-four-fold increase in photon flux over a standard 150-W high-pressure xenon arc lamp, which had been mounted in an ellipsoidal condensing mirror system, and whose radiation was distributed over a similar spectral range. The Eimac lamp's greater radiant power led to an approximate ten-fold lower detection limit for the fluorescence system studied.

The present paper examines several characteristics of a 300-W, integral-parabolic-reflector Eimac lamp which have proven important to its use in our

laboratory as a source for continuum-source atomic absorption spectrometry. These characteristics include spectral radiant power, noise characteristics, reflector optical quality, and arc image quality. While this lamp provides a substantially larger radiant power output than does its 150-W counterpart, the two models are expected to behave similarly with respect to the other characteristics to be discussed here.

EXPERIMENTAL

Lamps Used. The Eimac illuminator employed in this study incorporated a model VIX-300UV, 300-W lamp, which was operated horizontally within a model R300-1 fan-cooled housing, and was powered by a model PS300-1 current-regulated power supply (Varian Eimac Division, San Carlos, Calif.). The lamp contains an integral aluminum-coated parabolic collimator to provide high reflectivity over the range 250 to 3000 nm, and can be operated, with the power supply employed, over a current range of 13 to 20 A. Although the lamp-power supply combination will operate as low as 7A, information obtained from Varian Eimac suggested that operation at less than 13A could permanently decrease lamp stability. The Eimac lamp tested had approximately 25 hours of operating time out of a suggested useful lifetime of approximately 1000 hours.

The lamp used for comparison with the Eimac illuminator was a 150-W Hanovia 901C-11 high pressure xenon short-arc lamp (Englehard-Hanovia, Newark, N.J.) with associated housing and model 33-86-26 power supply (Bausch and Lomb, Rochester, N.Y.). This lamp had approximately 200 hours of operating time out of a suggested useful life 1200 hours. In operation, the 150-W Xe lamp draws approximately 7.5A at 20V from the supply. The housing contained no rear reflector, but was equipped with adjustable optics, which served to collimate the output radiation.

Spectral Radiant Power Measurement. A Scientech model 36-0001 disc calorimeter with a model 36-2001 power and energy indicator (Scientech, Inc., Boulder, Colo.) was employed in measuring spectral radiant output power from both the 300-W Eimac lamp (operated at 13, 15, and 18A) and the 150-W Hanovia lamp. The total output radiation of each lamp under test was passed through a 4 cm water filter to block unwanted radiation beyond 1200 nm, followed by a glass band-pass filter of peak wavelength = 527.3 nm, FWHM = 58.8 nm, and peak transmittance = 25.4%. The resulting transmitted radiation was focused via a lens (L_1; see table I) onto the disc calorimeter of the power meter and its power determined from the energy indicator meter. Outside the desired spectral region, the two-filter combination was found to be blocked to approximately $T = 10^{-3}$ between 300 nm (glass substrate cutoff) and 1200 nm (water filter cutoff), and to $T = \leq 10^{-5}$ beyond these limits to the ends of the 200 to 2100 nm lamp output range. It was estimated that this off-band-pass transmittance introduced less than 10% error in the lamp-power measurements.

Knowledge of the glass filter's nearly Gaussian transmittance function enabled calculation of the spectral radiant power (W/nm) of each lamp within that spectral region. Light losses introduced by the lens, L_1, and the water filter over the glass filter's spectral bandpass were estimated and accounted for in calculating spectral radiant powers.

Eimac Signal-to-Noise Characteristics. In studying the signal-to-noise ratio (S/N) of the Eimac lamp's output, the two optical arrangements shown in Figure 1 were employed. As is indicated in Figure 1A, the long focal length of the lens (L_2, see Table I) combined with the monochromator's 6.6° acceptance angle to define the acceptance of a 3.2 cm diameter column of light by the system. In this way, the radiation collected by the monochromator

and detected via a photomultiplier tube represented a spatially averaged sampling of the Eimac lamp's 2.54 cm diameter output beam.

In the second optical system, shown in Figure 1B, a much shorter focal length lens (L_3, see Table 1) was employed. This lens, together with the acceptance angle of the monochromator, defined the acceptance of a column of light which was only about 0.5 cm in diameter. As portrayed in Figure 1B, the spatial resolution provided by this optical system enabled a small cylindrical volume of the lamp's output beam to be selectively sampled by the monochromator and photodetector. In this way, spatially resolved signal-to-noise ratios within the output beam were determined.

It should be noted that a lamp warm-up time of at least 10 minutes was allowed before any S/N measurements were made; this length of time is twice that recommended by Varian.

Eimac Noise Power Spectrum. A noise power spectrum was determined for the noise present in the spatially averaged lamp radiation (i.e. employing optical system of Figure 1A). To obtain the power spectrum, the output signal from the PM tube was amplified, filtered, and then digitized using a PDP-12/40 minicomputer. The data was then Fourier transformed via a software-based fast-Fourier-transform routine, and the power spectrum was calculated from the transformed data. In order to reduce random fluctuations in the spectral data, nine data sets were collected and their power spectra averaged. In addition, the final data were smoothed using a three-point moving-window averaging routine.

In order to prevent aliasing, the preamplifier time constant was modified to provide a low pass filtering action, and its output was high pass filtered before digitization in order to remove the large dc component of the Eimac lamp's output (see Table 1 for filter characteristics).

Integral Reflector Optical Quality. Figure 2 is a photograph of the images formed when the radiation from first the Eimac lamp and then the 150-W Xe arc lamp were focused onto a screen via identical single-lens optical systems. The system employed was identical to that of Figure 1A, except that a screen replaced the monochromator entrance slit at the lens focal length, and the lens diameter was stopped down to 1 cm to improve the overall quality of the images.

In the process of photographing and printing these images, their relative sizes have not been altered.

To further demonstrate the effect of the relative image qualities attainable using these two lamps, the output beam of each was passed through a Keplerian beam-contracting telescope (i.e., telescope using two positive lenses) designed to shrink its input beam by a factor of 1.8. The collimated output beam of this telescope was then focused onto the entrance slit of the monochromator and detected via the photomultiplier (see Table I).

When a 1 mm diameter field stop was placed into the telescope to improve the collimation of the output beam, some loss in the intensity of the output beam naturally resulted. The extent of light loss for each lamp was determined, thus affording some indication of the quality of the image focused onto the field stop in each case.

RESULTS AND DISCUSSION

As noted earlier, the 300-W Eimac illuminator was purchased for use in our laboratory as a primary source of radiation for atomic absorption spectrometry. The lamp proved easy to align and incorporate into an optical system, and provided ample radiant power for our application. However, we

found that several important lamp characteristics were not entirely satisfactory and were not clearly specified in the scientific or Eimac product literature.

Spectral Radiant Power. That portion of the radiant power output of the Eimac and 150-W Xe arc lamps which was transmitted by a glass band-pass filter was measured using a thermopile-type detector. Average spectral radiant power (W/nm) for each lamp over the spectral region defined by the filter's band-pass was then calculated using these measured values, and the filter transmittance function. Table II lists the average spectral radiant powers determined for the Eimac lamp at several operating currents and for the 150-W Xe arc lamp. Heat build-up in the absorption (i.e., band-pass) filter precluded measurement of the power output of the Eimac lamp run at 20A (full 300-W input power). However, because the output power appears to be linear with lamp current, the data in Table II were extrapolated to obtain an average spectral radiant power value for 20A.

If one assumes, as suggested by the lamp specifications, that the radiant power output of the Eimac lamp is approximately flat over the visible range (400-800 nm), then the calculated spectral radiant power values of Table II can be considered valid over the entire visible range. The same approximation can be made for the 150-W Xe arc lamp. Accordingly, approximate values of total radiant power output over the visible region have been calculated for each lamp and appear in Table II along with the ratio of the calculated Eimac values to those calculated for the 150-W Xe arc lamp.

In Table II, the visible radiant power calculated for the Eimac lamp (operated at 20A) is only about 75% of the 16-W suggested by Varian. Regardless, the radiant power output of the Eimac lamp over the visible region is still as much as 37 times that of the 150-W Xe lamp. A simple consider-

ation of only the doubled power input and greatly increased solid angle of collection (2.65π sr for the Eimac lamp compared to approximately 0.28π sr for the short arc) of the Eimac lamp leads to a predicted radiant power increase of only 19X. Thus, greater lamp efficiency in addition to greater light-gathering ability is indicated for the Eimac lamp.

Eimac S/N Characteristics. A large component of the Eimac lamp's noise derives from turbulence in the hot gases which rise upward within the lamp itself in the region above the horizontally situated arc. Any radiation which passes through this turbulent region emerges from the lamp window with a degraded S/N. We have observed that radiation emerging from about a 20° slice at the top of the output window (see front view of lamp, corner of Figure 3) suffers this S/N degradation.

Figure 3 is a photograph of oscilloscope traces of the detected lamp radiation A) exclusively selected from the turbulent region, B) selected from the bottom of the lamp, away from the turbulent region, and C) without spatial selection to obtain a spatially averaged signal. From these data, a S/N of 236 (calculated assuming noise = Np-p/5) can be calculated for the radiation selected from the non-turbulent region (B in Figure 3). However, radiation selected from the turbulent region (A in Figure 3) has a S/N of only 48, a degradation by a factor of about five compared to B. As would be expected, spatial averaging of the output radiation (C in Figure 3) produces an intermediate S/N of 169. This spatially averaged S/N corresponds to about 3% p-p noise, which is within the 5% maximum noise specified by Varian for the 150-W Eimac arc lamps. No such specification is provided by Varian for the 300-W lamp.

As seen from the photograph in Figure 3, selecting light from the wrong area of this type of lamp could lead to a significant increase in detected noise. Particularly in optical arrangements in which radiation is imaged onto the entrance slit of a monochromator, careful attention should be paid to the inadvertent spatial selection of the source radiation which can occur.

Eimac Noise Power Spectrum. The frequency distribution of the noise present in the spatially averaged Eimac lamp radiation is depicted in Figure 4. Frequencies above 100 Hz, which were found to contain no noise power, have been filtered out of the spectrum, as have frequencies below approximately 0.6 Hz. All low-frequency data appearing in Figure 4 have been corrected for the attenuation caused by the filtering network (cf. Table 1). No data appear in Figure 5 below 0.6 Hz, because accurate correction for filter attentuation is not possible below this frequency.

The noise power spectrum indicates a strong 1/f (flicker) character in the lamp noise, with the power density rising sharply below 20 Hz. Structure visible on the rising part of the noise spectrum is believed to arise from arc wander and from gas turbulence within the lamp, as previously discussed. However, no further attempt was made by the authors to elucidate the true origin of these spectral features. The 1/f nature of the lamp noise indicates, at least for dc spectrometric applications of this source, that low-pass filtering with upper frequency cutoffs below 1 Hz could substantially reduce detected source noise, while cutoffs above 20 Hz would be expected to have little effect.

Integral Reflector Optical Quality. The rather poor image quality of the Eimac lamp (compared to that of the 150-W Xe arc lamp), as shown in

Figure 2, suggests that the lamp's arc is not properly positioned at the focal point of the parabolic reflector or that the reflector surface is of poor optical quality. Because Varian has confirmed that arc alignment within the test lamp is correct, the latter factor is probably responsible. Via personal communications (7), Varian explained that the reflector is formed by evaporating an aluminum coating onto a treated ceramic substrate, resulting in a somewhat low quality optical surface.

The effect of the reflector's optical quality was readily demonstrated when both the Eimac and 150-W Xe lamps were placed into a simple beam-contracting telescope, the collimated output radiation of which was imaged onto a monochromator entrance slit and detected. Placing a 1 mm field stop at the focal point of the telescope's object lens in an effort to improve output beam collimation resulted in a 60% light loss for the Eimac lamp (20A current), but only a 20% loss for the 150-W Xe arc lamp. The significant light loss seen with the Eimac lamp reflects the diffuse quality of the image formed on the field stop, and indicates that much of the radiant power advantage of this type of lamp may be lost in such an application.

REFERENCES

1) D.J. Johnson and J.D. Winefordner, Anal. Chem., **48**, 341 (1976).

2) M.P. Bratzel, Jr., R.M. Dagnall, and J.D. Winefordner, Anal. Chim. Acta, **52**, 157 (1970).

3) D.J. Johnson, F.W. Plankey, and J.D. Winefordner, Anal. Chem., **46**, 1898 (1974).

4) R.L. Miller, L.M. Fraser, and J.D. Winefordner, Appl. Spec., **25**, 477 (1971).

5) A.T. Zander and T.C. O'Haver, Anal. Chem., **48**, 1166 (1976).

6) R.J. Perchalski, J.D. Winefordner, and B.J. Wilder, Anal. Chem., **47**, 1993 (1975).

7) D. Wilson, Varian Eimac Division, personal communication, 1976.

Table 1 Optics and Spectrometer

Optics	L_1, diameter = 5.1 cm, F.L. = 9.5 cm. L_2, diameter = 5.0 cm, F.L. = 28 cm. L_3, diameter = 4.7 cm, F.L. = 5.7 cm.
Monochromator	0.35-m Czerny-Turner mount, grating monochromator (no. EU-700, GCA/McPherson Instrument, Acton, Mass.). Acceptance angle 6.6°. Used with 3 mm aperature disc at the entrance slit. Wavelength setting = 550 nm. Spectral slit width = 0.1 nm.
Photodetection	RCA 1P28 photomultiplier tube, powered by a regulated high voltage supply (no. 245, Keithley Instruments, Inc., Cleveland, Ohio). Output current converted to a proportional voltage by model 215 operational amplifier, upper cut-off frequency = 796 Hz, (Princeton Applied Research Corp., Princeton, N.J.). OA output monitored via an oscilloscope (model PM 3233, N.V. Phillips, Eindhoven, The Netherlands).
Power Spectrum Filtering	Model 215 operational amplifier upper-cutoff frequency reduced to 159 Hz. High pass filter had a lower cutoff frequency of 0.24 Hz. Cutoff frequencies measured at 3dB.

TABLE II RADIANT POWER CHARACTERISTICS

Lamp	Current (A)	Average Spectral Radiant Power (W/nm)	Calculated Radiant** Power Over Spectral Region 400-800 nm (W)	Ratio of Average Spectral Radiant Powers (Eimac/150-W)
Eimac	13	0.015	6.0	19
Eimac	15	0.019	7.6	24
Eimac E	18	0.025	10	32
Eimac	20	0.029*	12	37
150 Xenon	--	7.8×10^{-4}	0.13	1

*extrapolated value.

**Assumes flat spectral radiant power output over 400-800 nm region.

FIGURE CAPTIONS

Figure 1 OPTICAL SYSTEMS FOR S/N DETERMINATIONS

(A) spatially averaging

(B) spatially selecting

(---) light path;

(——) monochromator acceptance. all measurements in cm

Figure 2 IMAGES FORMED FROM TEST LAMPS (See text for discussion)

(A) from Eimac lamp

(B) from 150-W Xe lamp

Figure 3 SCOPE TRACINGS OF LAMP NOISE

(A) from turbulent region

(B) from non-turbulent region

(C) spatially averaged

(corner) front view of lamp showing turbulent region

scope horizontal scale = 10 msec/division

scope verticle scale = 0.5 V/division for trace A; decreased slightly to offset traces B and C.

Figure 4 EIMAC LAMP NOISE POWER SPECTRUM (see text for explanation)

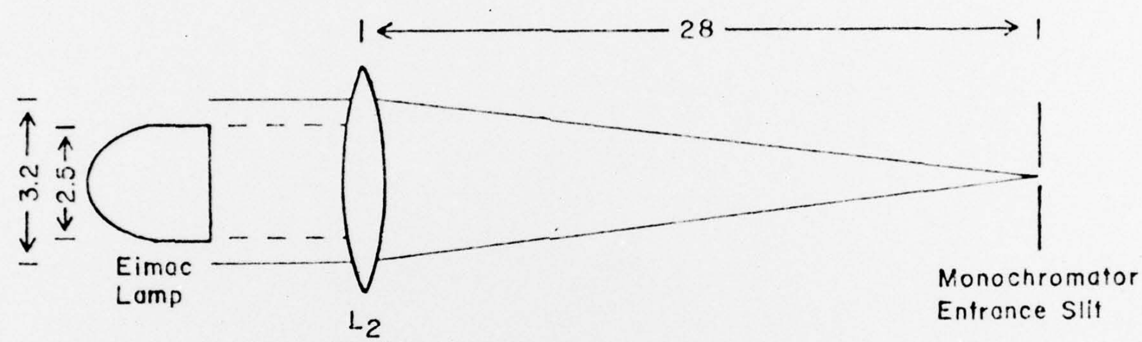
y-axis in relative units

ACKNOWLEDGEMENT

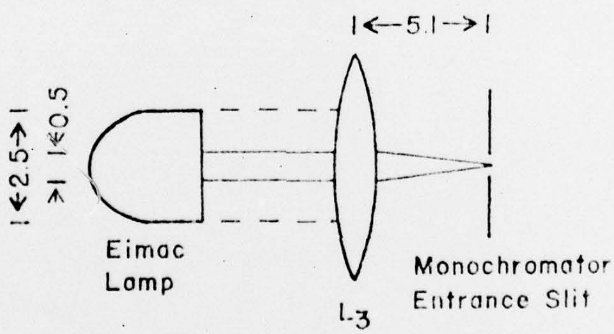
The authors wish to thank J.M. Ramsey for providing the fast Fourier transform software required to obtain the noise power spectrum of the Eimac lamp.

CREDIT

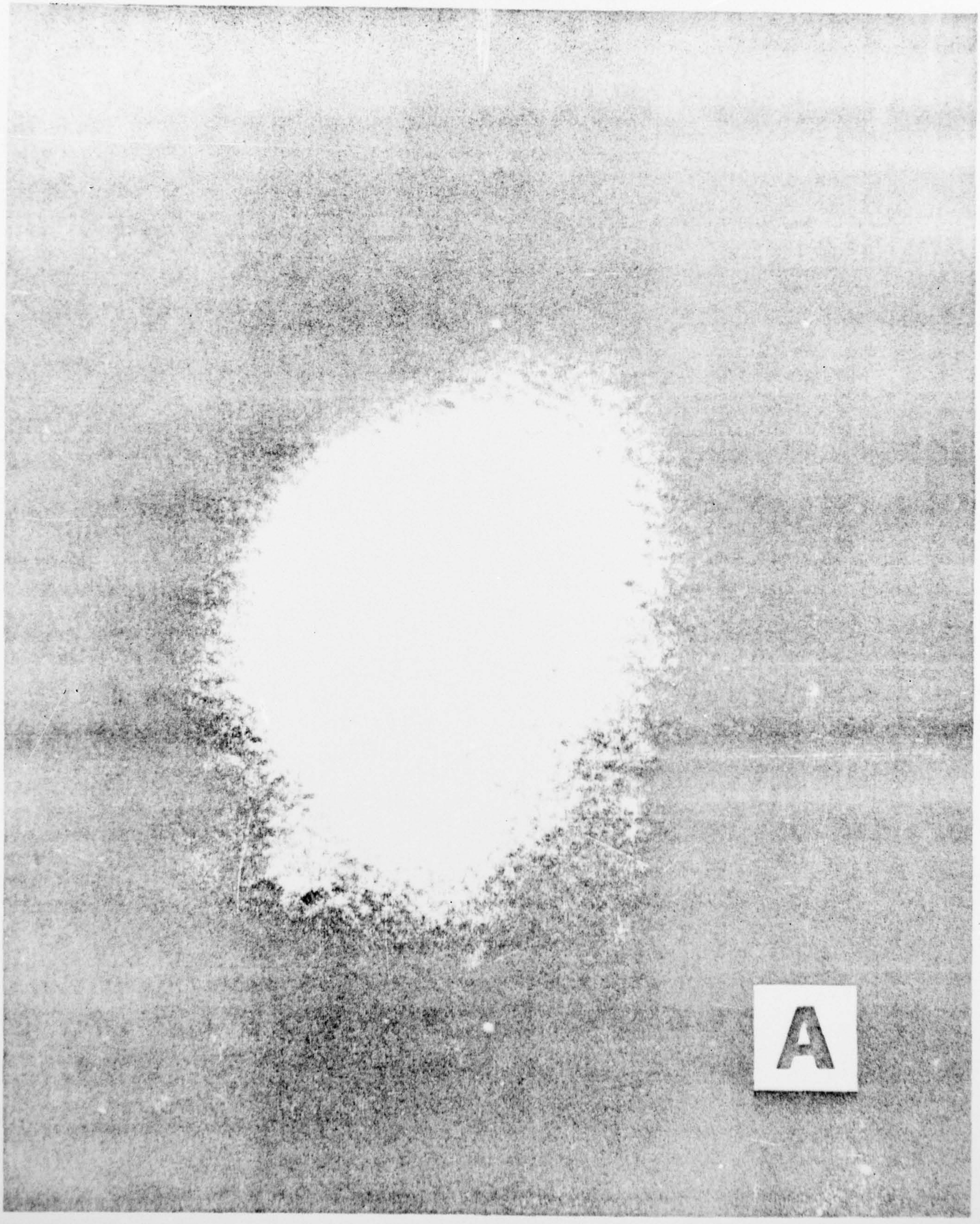
This research was supported in part through the Office of Naval Research and through National Science Foundation grant CHE 76-10896.

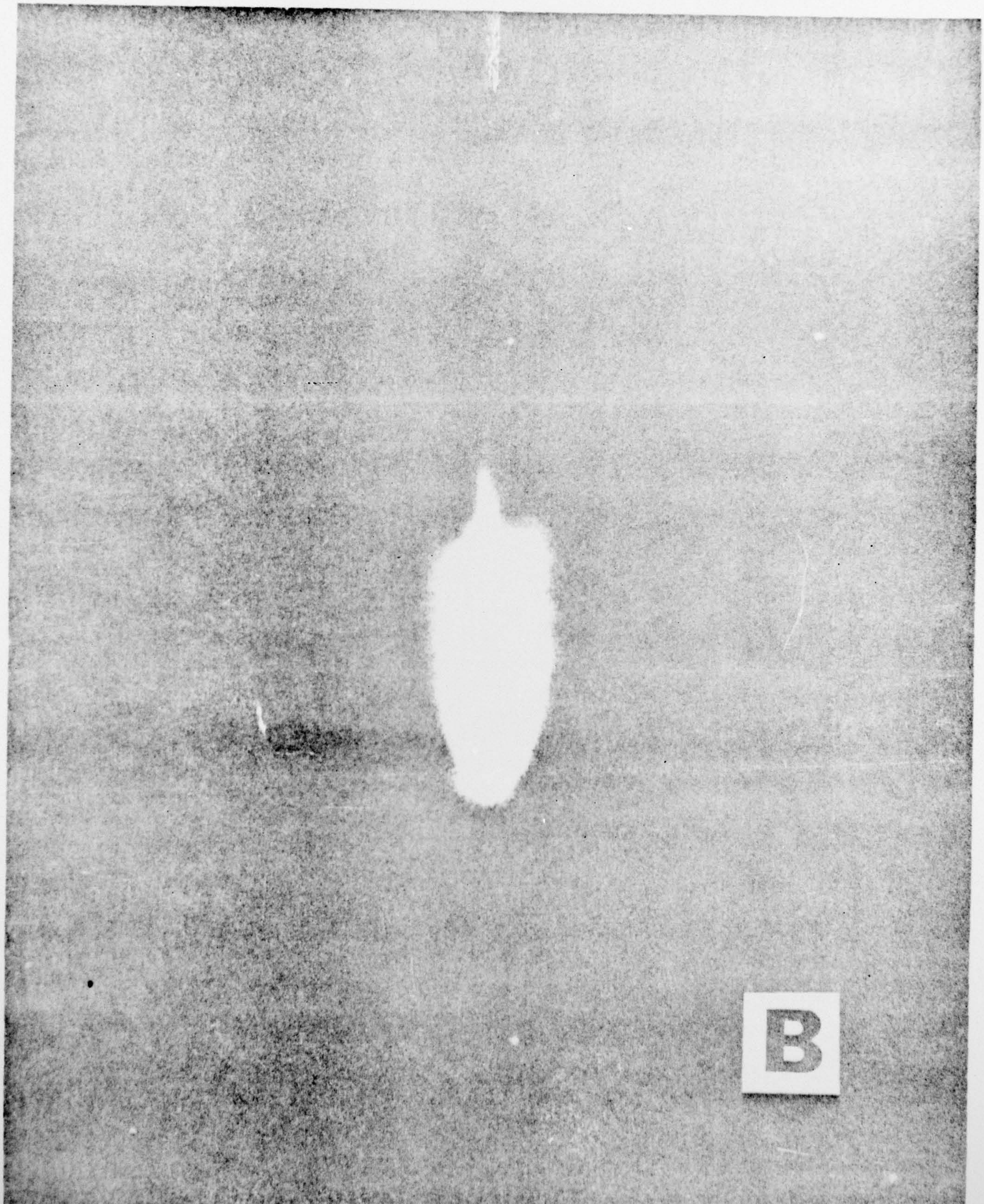

28
3.2
2.5
Eimac
Lamp
L_2
Monochromator
Entrance Slit

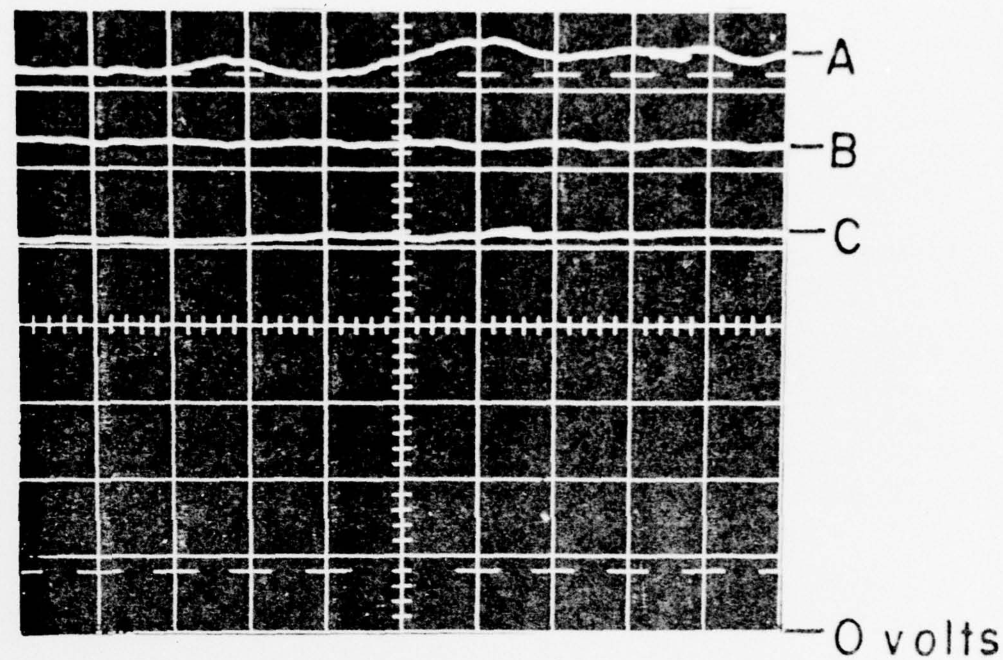
A

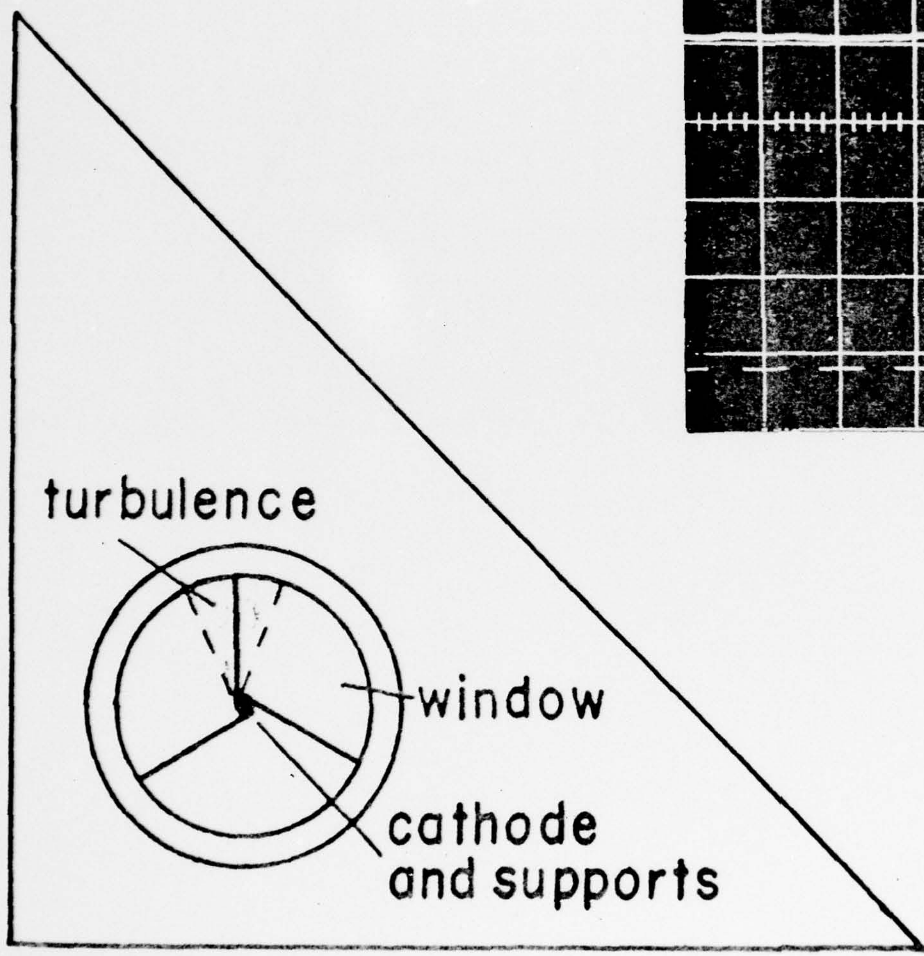

5.1
2.5
0.5
Eimac
Lamp
L_3
Monochromator
Entrance Slit

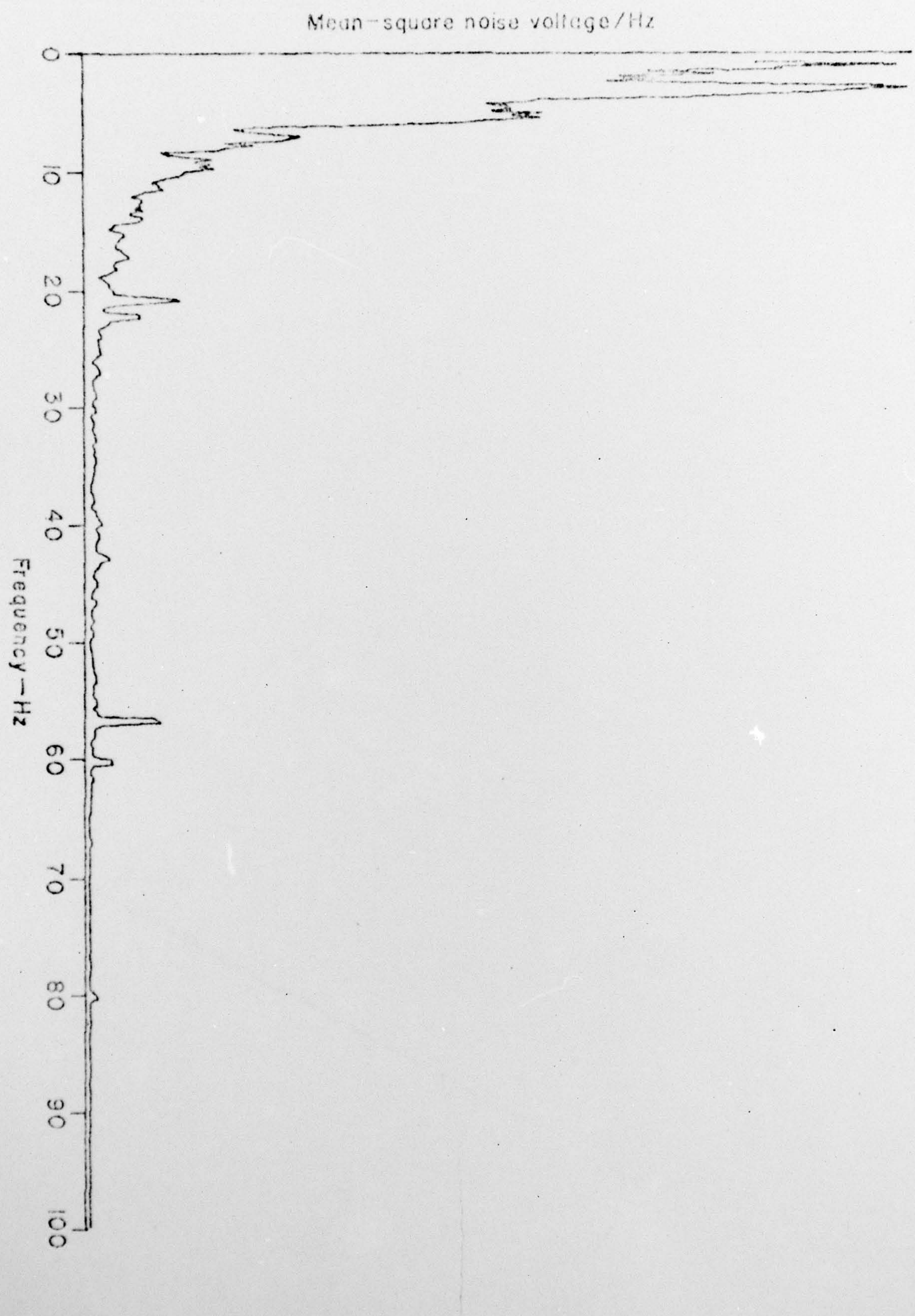
B


A


B


A
B
C
O volts


turbulence
window
cathode
and supports


Mean-square noise voltage/Hz
Frequency—Hz
0
10
20
30
40
50
60
70
80
90
100

TECHNICAL REPORT DISTRIBUTION LIST

	No. Copies
Office of Naval Research Arlington, Virginia 22217 Attn: Code 472	2
Office of Naval Research Arlington, Virginia 22217 Attn: Code 102IP	6
ONR Branch Office 536 S. Clark Street Chicago, Illinois 60605 Attn: Dr. Jerry Smith	1
ONR Branch Office 715 Broadway New York, New York 10003 Attn: Scientific Dept.	1
ONR Branch Office 1030 East Green Street Pasadena, California 91106 Attn: Dr. R. J. Marcus	1
ONR Branch Office 760 Market Street, Rm. 447 San Francisco, California 94102 Attn: Dr. P. A. Miller	1
ONR Branch Office 495 Summer Street Boston, Massachusetts 02210 Attn: Dr. L. H. Peebles	1
Director, Naval Research Laboratory Washington, D.C. 20390 Attn: Library, Code 2029 (ONRL)	6
Technical Info. Div.	1
Code 6100, 6170	1
The Asst. Secretary of the Navy (R&D) Department of the Navy Room 4E736, Pentagon Washington, D.C. 20350	1
Commander, Naval Air Systems Command Department of the Navy Washington, D.C. 20360 Attn: Code 310C (H. Rosenwasser)	1

	No. Copies
Defense Documentation Center Building 5, Cameron Station Alexandria, Virginia 22314	12
U.S. Army Research Office P.O. Box 12211 Research Triangle Park, North Carolina 27709 Attn: CRD-AA-IP	
Commander Naval Undersea Research & Development Center San Diego, California 92132 Attn: Technical Library, Code 133	1
Naval Weapons Center China Lake, California 93555 Attn: Head, Chemistry Division	1
Naval Civil Engineering Laboratory Port Hueneme, California 93041 Attn: Mr. W. S. Haynes	1
Professor O. Heinz Department of Physics & Chemistry Naval Postgraduate School Monterey, California 93940	
Dr. A. L. Slafkosky Scientific Advisor Commandant of the Marine Corps (Code RD-1) Washington, D.C. 20380	1

TECHNICAL REPORT DISTRIBUTION LIST

	No. Copies
Dr. M. B. Denton University of Arizona Department of Chemistry Tucson, Arizona 85721	1
Dr. G. S. Wilson University of Arizona Department of Chemistry Tucson, Arizona 85721	1
Dr. R. A. Osteryoung Colorado State University Department of Chemistry Fort Collins, Colorado 80521	1
Dr. B. R. Kowalski University of Washington Department of Chemistry Seattle, Washington 98105	1
Dr. I. B. Goldberg North American Rockwell Science Center P.O. Box 1085 1049 Camino Dos Rios Thousand Oaks, California 91360	1
Dr. S. P. Perone Purdue University Department of Chemistry Lafayette, Indiana 47907	1
Dr. E. E. Wells Naval Research Laboratory Code 6160 Washington, D.C. 20375	1
Dr. D. L. Venezky Naval Research Laboratory Code 6130 Washington, D.C. 20375	1
Dr. H. Freiser University of Arizona Department of Chemistry Tuscon, Arizona 85721	

	No. Copies
Dr. Fred Saalfeld Naval Research Laboratory Code 6110 Washington, D.C. 20375	1
Dr. H. Chernoff Massachusetts Institute of Technology Department of Mathematics Cambridge, Massachusetts 02139	1
Dr. K. Wilson University of California, San Diego Department of Chemistry La Jolla, California 92037	1
Dr. A. Zirino Naval Undersea Center San Diego, California 92132	1
Dr. John Duffin United States Naval Post Graduate School Monterey, California 93940	1
~~Dr. G. M. Hieftje~~ ~~Department of Chemistry~~ ~~Indiana University~~ ~~Bloomington, Indiana 47401~~	1
Dr. Victor L. Rehn Naval Weapons Center Code China Lake, California 93555	1